From Printing Graphics to Printing Electronics, The Digital Revolution in Display Manufacturing

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Abstract

In this paper we present work done by Kodak Graphic-Communications-Group and our partners demonstrating applications where laser direct imaging could replace photolithography in display manufacturing. Such applications range from direct manufacturing (e.g. LCD color-filters) to producing "masters" where manufacturing is done by traditional printing methods (e.g. flexography, Gravure-printing).

1. Introduction

The constant push to reduce prices is forcing display manufacturers to continuously look for cheaper manufacturing methods. One of the main cost drivers in display manufacturing is patterning. The process of manufacturing a modern display includes several steps of patterning that are conventionally done by photolithography. Photolithography certainly delivers the level of quality that is required in modern displays but it requires costly equipment and, being a subtractive process, also considerable chemical infrastructure for handling the developing, stripping and etching steps that follow the patterning step. In addition, photolithography does not handle flexible substrates very well and this limitation is ever more noticeable as manufactures try to replace glass with flexible substrates to further reduce costs and weight and also develop flexible displays.

The printing industry has mastered technologies for patterning flexible substrates with low-cost, hi-resolution and hi-productivity over many years and is a natural candidate to offer solutions to the emerging needs of the display industry.

Laser imaging is today the predominant patterning method used in Computer-To-Plate (CTP) applications in the graphic arts industry with thousands of systems worldwide. More specifically, thermal laser imaging and thermal processes have become so widely spread that the quantity of thermal resists sold annually world-wide is approaching the quantity of annual photo-resist sales.

The use of laser direct imaging for manufacturing LCD color filters and inkjet barrier ribs has already been presented [1]. In addition to eliminating costly masks, laser direct imaging offers material savings, considerable savings in clean room space and elimination of wet chemistry and related infrastructure. Kodak Graphic Communications Canada Company has developed a Gen 7 laser imaging system for the DuPont new manufacturing system for LCD color-filters – Thermal Color Filters (TCF). This system is shown in Fig. 1.

Fig. 1. Gen 7 LCD Color Filter Machine developed by Kodak for DuPont TCF Process.

In recent work done by Kodak Graphic Communications Canada and our partners we discovered further uses for laser direct imaging in various parts of the display manufacturing process. While in some applications, such as LCD color filters,

the laser-imaging device is the sole patterning tool, in other applications, such as inkjet barrier ribs and surface energy patterning, laser imaging is used in conjunction with inkjet and other liquid deposition methods to improve the accuracy of the patterning process. In yet further applications, such as conductor sintering, laser imaging could be used as a post-processing tool to improve material properties after deposition. Finally, as manufacturers start using conventional printing methods (flexography, gravure, etc.) laser imaging could provide the means to create the printing plates and cylinders for the process just like Computer-To-Plate applications in Graphic Arts.

2. Results

Inkjet has become widely spread as a material deposition method in display manufacturing. It offers excellent parallelism, volumetric accuracy, efficient material use and material versatility. However, inkjet systems lack in spatial accuracy and critical dimension (CD) control. These shortcomings could be overcome by combining laser direct imaging in the patterning process. One method for doing that is the use of barrier ribs [1]. Yet another way to achieve this improvement is by using surface energy patterning. First, the substrate is coated with a material that changes surface energy under laser imaging. Following that a surface energy pattern is created on the substrate. Liquid is then deposited, using inkjet or other liquid deposition methods, aligning itself appropriately according to the surface energy pattern. For example, if the ink is water-based, the surface energy could change from hydrophobic to hydrophilic (or vice-versa) under laser imaging and the ink will then cover only the hydrophilic areas. Thanks to the high resolution of laser imaging systems, the resolution achievable with such technique is much higher compared to the natural resolution of liquid deposition methods.

It is worthwhile to note that a similar process is successfully used commercially for many years in offset printing where the printing plate is the substrate onto which a surface energy pattern is imaged using lased direct imaging.

This technique was successfully applied by Plastic-Logic in their process for making organic transistors achieving critical dimensions as low as 3 um.

In the past few years inkjet has also become widespread in conductor patterning using specially formulated nano-particle inks [2]. In order to achieve high conductivity the ink has to be heated, following deposition, to evaporate the liquid in which the nano-particles are immersed and allow agglomeration. Such heating may not be compatible with flexible substrates as it might cause deformation. Laser direct imaging could be used to selectively heat the conductor lines for this purpose without any change in underlying substrate temperature. This process has been successfully demonstrated by Kodak with significant conductivity improvement.

Recently, manufacturers have started looking into the potential of using conventional printing methods (flexography, gravure, etc.) for display and electronics manufacturing [3]. Such systems could offer resolution as good as 10 um and better and could provide a cheap alternative for low cost flexible display manufacturing. Here laser imaging could provide the means to create the printing plates/cylinders just like Plates is Computer-To-Plate applications in Graphic Arts.

4. Summary

The work presented in this paper demonstrates the ever-increasing number of uses for laser direct imaging in display manufacturing. The potential for cost reduction and process simplification is huge. As demonstrated, a laser-imaging device is extremely versatile and may become a universal tool for display manufacturing.

5. References

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